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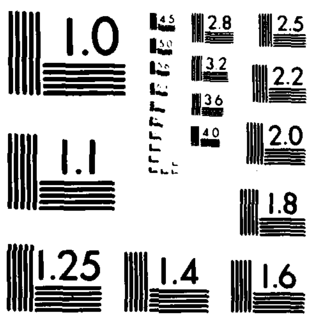

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Global Positioning satellites have been tested under a variety of conditions and have demonstrated exceptional accuracy. The most portable of the Phase I development equipment is the manpack/vehicle user equipment (MVUE of manpack). The purpose of this study was to determine if a manpack is suitably accurate for large scale coastal hydrographic surveying. The manpack was placed aboard the Naval Postgraduate School Research Vessel, R/V ACANIA ~~and operated under survey conditions~~ in Monterey Bay, California. This objective required the (over)

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HYDROGRAPHIC APPLICATIONS OF THE GLOBAL POSITIONING SYSTEM

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ABSTRACT

Global Positioning satellites have been tested under a variety of conditions and have demonstrated exceptional accuracy. The most portable of the Phase I development equipment is the manpack/vehicle user equipment (MVUE or manpack). The purpose of this study was to determine if a manpack is suitably accurate for large scale coastal hydrographic surveying. The manpack was placed aboard the Naval Postgraduate School Research Vessel (R/V) ACANIA and operated under survey conditions in Monterey Bay, California. This objective required the testing of the manpack developed by Texas Instruments, Inc., under varying survey conditions to determine the degradation of positional accuracy. The limit of the survey scale to which the unprocessed manpack data could be employed in a real-time operation was found to be 1:80,000 and smaller by the positioning error criteria of 0.5mm to the scale of the survey (Umbach, 1976). Applications of differential techniques during the post-processing of the manpack position data increased the limit of the survey scale to 1:60,000 using the same position criteria.

INTRODUCTION

The NAVSTAR Global Positioning System (GPS) is designed to be the most advanced three-dimensional navigation and positioning system in the world in terms of accuracy, coverage, and availability to all potential users. Testing emphasis of the system has been in the area of high positional and navigation accuracy as applied to military usage. Of importance to military operations is the need for accurate maps and charts. Tests to this date have not addressed this need.

This test was conducted to determine the positional accuracy of the Texas Instruments manpack receiver and the scale of survey to which it is applicable. Several criteria exist for determining positional accuracy. The International Hydrographic Bureau (IHB) states that positional error shall seldom exceed 1.5mm at the scale of survey [1]. The National Ocean Survey (NOS) Hydrographic Manual has adopted this criteria with the further stipulation that of the 1.5mm, approximately 0.5mm is reserved for position error[2]. For our test, we adopted the modification outlined by Admiral R. C. Munson, i.e., "seldom" will be taken to mean less than 10 percent of the time and the 1.5mm value will be interpreted as a 90 percent accuracy level. [3]. Hydrographic operations will benefit from the implementation of NAVSTAR GPS in several ways: positional accuracy; continuous, worldwide, all weather availability; simplification of survey operations; and cost reduction [4].

HYDROGRAPHIC TEST PROCEDURES

A test plan was drawn up prior to the test itself and covered three major areas. The first was a series of equipment installation tests. These were designed to determine that all the cables and antennas were properly connected, power sources were stable, and the Mini-Ranger and the manpack receiver were operating within design specifications.

The second major series of tests were the performance evaluation tests. These involved a static test where the receiver antenna was set up over a known second-order control station; a pier test to subject the receiver to low dynamic conditions; and an anchor test designed to subject the receiver to moderately dynamic conditions.

The third major series of tests were survey operation simulations. The manpack was installed aboard the Naval Postgraduate School Research Vessel (R/V) ACANIA, a 120-foot vessel outfitted for oceanographic work. Since the ACANIA's maximum speed is 9 knots, some adjustments had to be made in the testing to simulate real conditions.

The high dynamic test was run to determine if the satellite signal was lost simulating acceleration normally experienced during inshore surveying. The circle runs were designed to determine if any radial error was introduced in positions. The 5- and 9- knot lines were the closest approximation of normal survey procedures.

The testing covered a period of 9 days: April 30 through May 8, 1980. Tests were conducted at night between 2000 and 0400 local time because that was the period of optimum satellite availability. Weather was good for the entire testing period. Table I gives a breakdown of the data collected daily by line.

ERROR ANALYSIS

A fairly lengthy error analysis procedure was gone through due to the volume and variety of data collected. Table II gives a breakdown of the error associated with component. It was found that the average error was 7 meters. Table III gives a breakdown of the error associated with the satellite system. [5]. This error averages out to 5 meters for a total error of 12 meters. Taking the best data, computations produced a mean offset of 38+12 meters. If the error total of 12 meters is removed, a corrected value of 26+12 meters is obtained.

CONCLUSION

With updated satellite ephemeris and using stable satellites, results indicate that the MVUE manpack will provide the accuracy required for real-time standard medium scale coastal hydrographic operations of 1:80,000 and smaller by the 0.5mm criteria (40 meters).

Post processing of data may bring the accuracies into the large scale 1:60,000 range. Problems associated with the operation of the navigation filters in the receiver need to be resolved, however, before any determination can be made as to further improvement in accuracy.

REFERENCES

1. "IHB Special Publication 44, Accuracy Standards Recommended for Hydrographic Surveys". International Hydrographic Bureau, Monaco, 1968.

2. Umbach, Hydrographic Manual, Edition 4, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Survey, 4 July 1976.

3. Munson, R.C., Rear Admiral, Positioning Systems, NOS Publication, June 1977.

4. Navigation Aid Support Unit (NAVAIDS) UNCLASSIFIED Letter NAVAIDS/01:lvt 12000 Ser 80 to Penny Dunn, Subject: NAVAIDSUPPUNIT Operation Costs; Request for, 6 June 1980.

5. Millikin, R. J. and Toller, D.J., "Principle of Operation of NAVSTAR and System Characteristics", Navigation, v. 25, No. 2, SUmmer 1978.

Table I - Track Line Data Log

Day	Line	Offset (d)	σ	Azimuth [illegible] Mean d°	σ°	Time (GMT)	[illegible] Events	[illegible] (Low, High)	Line Direction (from North)	Velocity		Number of Satellites
121 (Beach)	L1	23	-	77	-	0605-0607	5	-		dynamic 25 m/sec		4
	L2	36	10	134 (120-140)	10	0811-0844	68	d - high right σ - high right		dynamic 25 m/sec		4
122 (Pier)	L1	102	85	341 (335-350)	4	0710-0725	57	d - high left σ - high right		-		2
	L2	87	12	53 (9-80)	11	0846-0912	83	d - high left σ - high right		-		2
123 (Anchor)	L1	150	95	302 (290-310)	6	0736-0814	113	-		-		4
124 (High Dynamic)	L1	310	20	29.3	7	0600-0647	171	σ - high left	345°	(M/S) 4.5	(Knots) 8.7	3/2
	L2	1003	150	100	5	0727-0811	166	-	075°	4.5	8.7	2
125 (Circle and Lines)	L1	31	13	100	14	0540-0620	129	-	circle left	4.5	8.7	3
	L2	30	27	292	21	0638-0718	122	-	circle right	4.5	8.7	4
	L3	297	266	132 (90-120)	19	0755-0820	74	d - high left/ low right	000°	4.5	8.7	4/5
	L4	268	166	112 (70-140)	24	0826-0839	51	d - high left	180°	4.3	8.4	5/4
	L5	21088	4674	267 (254-270)	3	0901-0920	54	d - high right	270°	4.4	8.6	4
	L6	-	-	-				-	090°	4.3	8.4	4
126 (Nine Knot Lines)	L1	102	5	197 (190-210)	4	0558-0615	62	-	270°	4.0	7.8	3
	L2	116	7	188 (180-195)	5	0622-0637	33	-	090°	4.0	8.6	3
	L3	363	100	121 (115-130)	4	0652-0708	62	d - high left	270°	3.7	7.2	4
	L4	54	41	125 (100-150)	11	0744-0800	60	-	180°	4.0	7.8	4
	L5	20	7	152 (120-190)	21	0809-0824	58	σ - high right	000°	3.7	7.2	4
	L6	33	10	240 (210-280)	13	0844-0902	70	d - high left	135°	3.9	7.6	3
	L7	42	10	262 (250-280)	6	0617-0936	59		045°	3.5	6.8	3
	L8	55	13	282 (275-300)	7	0950-1007	63	σ - high right	270°	2.7	5.2	3
127 (Five Knot Lines)	L1	671	133	152 (140-170)	8	0646-0700	36	- high left	300°	3.5	6.5	3/2
	L2	187	176	119 (115-125)	2	0721-0729	33	-	120°	3.7	7.2	4
	L3	50	10	133 (125-140)	5	0737-0750	44	-	300°	3.8	7.4	4
	L4	32	13	157 (140-200)	13	0800-0815	53	-	210°	3.9	7.6	4
	L5	33	22	158 (145-210)	17	0822-0833	40	-	30°	3.7	7.2	4
	L6	33	11	218 (200-225)	12	0858-0915	61	-	210°	3.8	7.4	3
128 (Beach)	L1	49	65	317 (0-360)	25	0631-0705	70	-	-	static &		4
	L2	7	3	313 (0-360)	29	0735-0805	49	d - high left σ - high left	-	static 0		4

A.	Geodetic Control	.4m
B.	Position Error[1] (due to coordinate shift)	4m
C.	Inverse[2] (Ellipsoid vs. Plane Computation)	.02m
D.	GDOP	4m
E.	Range Correction	3m
F.	Meteorological	.06m
G.	Station Elevation	.1m
H.	Timing[3]	0 - 4 m
I.	MRS III Positioning	.5m
J.	Antenna Motion	0 - 2 m

1 - Based on offset between Doppler station and abridged Molodensky Formulas
2 - Maximum at distances less than 1000 meters
3 - Depends on trends in data

TOTAL ERROR

$$E_{T_{min}} = e_A + e_B + e_C + e_D + e_E + e_F + e_G + e_H + e_I + e_J$$

$$= .4^2 + 4^2 + .02^2 + 4^2 + 3^2 + .06^2 + .1^2 + 0 + .5^2 + 0$$

with e_H (timing) = 0 and e_J (antenna motion) = 0

$= 6.4m$

$$E_{T_{max}} = .4^2 + 4^2 + .02^2 + 4^2 + 3^2 + .06^2 + .1^2 + 4^2 + .5^2 + 2^2$$

with $e_H = 4m$ and $e_J = 2m$

$= 7.8m$

$E_{T_{avg}} = 7m$

RAW DATA: 38 meters with 11 meter standard deviation

CORRECTED: 38 - 7 = 31 meters

Table II - Error Analysis Associated with Test Area and Equipment

Uncorrected Error Source	User Equivalent Range Error, 1	
	Meters	Feet
SV Clock Errors Ephemeris Errors	1.5	5.0
Atmospheric Delays	2.4-5.2	8.0-17.0
Group Delay (SV Equipment)	1.0	3.3
Multipath	1.2-2.7	4.0-9.0
Receiver Noise and Resolution Vehicle Dynamics	1.5	5.0
RSS	3.6-6.3	11.8-20.7

[Millikin, et.al., 1978]

Table III - Error Analysis Associated with Satellite System